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ECO-PIANO MODEKAL

Abstract: For the major part of contemporary composers, the main field of interest is electroacoustic music. On the one hand, the capabilities of classical instruments often no longer satisfy composers – they see more creative potential in music programming; on the other hand, this interest is driven by the composers' desire to have their composed works performed, the realization of which is much easier at the expense of technologies. These trends have clearly created a shortage of new sounds in instrumental music. It is important to maintain instrumental music and to make its existence suitable for the modern environment. To solve this problem, an upright piano "Zarya" was modified according to the principles of modern musical thinking and very topical ecomusicology into the piano called ModEkAl. The modified piano is a new type of piano constructed for the artistic research 'Has Piano Music Come to an End?' conducted by composer Eka Chabashvili and pianists Nino Jvania and Tamar Zhvania. The piano was modified according to Chabashvili's scheme which was enriched with the ideas of piano master Alexander Zirakashvili. The paper describes the modified instrument in detail, and introduces a new notation system designed exclusively for the ModEkAl.

Keywords: modified piano; eco-piano; artistic research; new notation; new tuning system.

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Introduction

A musical instrument always echoes the epoch it was created in. With its structure, tuning system, and performance techniques, it could be considered a musical chronicler that tells a lot about the musical aesthetics of the age it belongs to. The principles of musical thinking characteristic of any new epoch lead to the transformation of an instrument, its renewal, refinement, or the enrichment of its performance technique. Each era adapts the instrument to the principles of the corresponding musical thinking so that the instrument's sound has a truly contemporary essence. When modifying any instrument, it is necessary to take into consideration the cultural memory stored within it. We have numerous vivid examples of instrument modifications (ancient and modern flutes, antique hydraulic and contemporary electronic organs, etc.). In all cases, the instruments retain their essence.

The purpose of the article is to present a modified piano ModEkAl and to describe the principle and process of modification. Experiments were carried out on the piano "Zarya" manufactured in the Soviet Union in the 70s of the previous century. The piano was modified according to composer Eka Chabashvili's scheme which was enriched with some ideas of piano master Alexander Zirakashvili. The name of the instrument derives from a combination of the names of its creators – Piano Modified by Eka and Alexander.

The ModEkAl was constructed as the outcome of the artistic research work "Has Piano Music Come to an End?" conducted by the composer and two pianists, associate professors of the Vano Sarajishvili Tbilisi State Conservatoire, Nino Jvania (pianist), Eka Chabashvili (composer), and an assistant professor Tamar Zhvania (pianist), respectively.

The artistic research title alludes to the words of Karlheinz Stockhausen, one of the most influential composers of New Music. "(P)iano music has come to an end and something quite different is coming. I see it clearly: with the claviers made up to this time, there is nothing new to discover any more", declared Stockhausen in 1992.[1] As Nino Jvania states,

> It is difficult not to agree with the German composer who nevertheless continued to compose for piano both before and after 1992. However, the fact is that contemporary composers engage themselves less and less with the piano – particularly as a solo instrument. [….] It is difficult to imagine what further innovations

[1] Karlheinz Stockhausen, "Clavier music 1992", *Perspectives of New Music*, 31 (2), 1993, 138.

> the acoustic piano could present to listeners, even with the addition of electronic technologies. So, has piano music really come to an end? One of the best ways to answer it is to conduct an artistic research.[2]

The birth of the pianoforte was a response to particular ongoing processes in music. Because of radical changes happening in art music since the second half of the 20th century, the piano faced a certain crisis Stockhausen speaks so openly about. The concept of a musical sound has been re-evaluated which resulted in the integration of noises in music on one hand, and the employment of technologies in music production and composition on the other. As a result, to paraphrase Stockhausen, timbre and timbre-oriented pieces gain in importance, whereas monochrome pieces are almost ignored.[3] Despite conceding leading positions, piano music attempts to support these changes. Since the piano *replaced* its predecessors, it has constantly been developing, including improvement of the mechanism, changes in size, etc. In the new epoch, the abilities of the piano are expanding further, resulting in the emergence of prepared and quartertone pianos, the development of extended techniques, etc. In this context, it seemed very logical to create a new, modified version of the piano within the framework of this particular artistic research.

1. Modification of the Piano and its Transformation into the Eco-Piano

"Let us take thought, of how music may be restored to its primitive, natural essence; let us free it from architectonic, acoustic, and esthetic dogmas," declared Ferruccio Busoni in his "Sketch of a New Esthetic of Music" at the beginning of the 20th century, predicting future interest in the ecology of music and sound.[4]

The most urgent challenge of the 21st century is ecology; many teachings aim to awaken the awareness of people to protect our environment, to save our planet and humanity. The search for ways to solve environmental prob-

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[2] Nino Jvania, "Composer-Performer Interaction as a Source of Idea Generation: Presenting Artistic Project 'Piano of the 21st Century and Its Future Perspectives", in: Aleksandra Pijarowska et al. (Eds), *Music – the Cultural Bridge: Essence, Contexts, References*, Wroclaw, Akademia Muzyczna im. Karola Lipińskiego we Wrocławiu, 2021, 273.

[3] Karlheinz Stockhausen, "Japanische Klaviermusik", in: Dieter Schnebel (Ed.), *Texte zur Musk:1963–1970*, Band 3, Koeln, DuMont Buchverlag, 1971, 348.

[4] Ferruccio Busoni, *Sketch of a New Esthetic of Music*, transl. by Dr. Theodore Baker, New York, G. Schirmer, 1911, 34.

lems is a topical issue in almost every field, including music, because sound and music itself are part of the Earth's ecosystem. Therefore, they can positively or negatively affect the environment. In 2011, Aaron Allen posted a question: "Is the environmental crisis relevant to music—and more importantly, is musicology relevant to solving it?"[5] This question is logical and topical nowadays too. All events should serve the protection of the natural environment, be it the processes or the results of geographical, industrial, psycho-physiological, or artistic projects.

If Stockhausen's prediction about *something quite different that is coming* is, to a certain extent, relevant today, like the need for a new instrument was topical three centuries ago, our modified piano could be regarded as one of the keyboard instruments that answers the demands of music of the present and the future.

The piano was modified based on approaches characteristic of contemporary musical thinking and ecomusicology. Thus, we set the task to create an eco-friendly piano. During the modification process, the main focus was set on:

- The timbre that could be considered the most important sound parameter in contemporary professional music;
- The tuning system; we tried to incorporate into the tuning process the natural sound characteristics and to choose the harmonic sequences of fundamental tones as the main source for the tuning.

The main goal during the piano modification process was to combine the cultural memory archived in the instrument with the principles of 21st-century musical thinking. Consequently, the instrument's creators aimed:

- To maintain the basic principle of operation of the instrument's mechanism – producing the sound by hitting a hammer on strings and employing the pedals;
- To maintain the traditional form of the instrument's sound production – playing the keys.

The piano was modified based on the accumulated information and experience in the field of extended piano techniques of the 20th and 21st centuries. The ModEkAl creators hope to offer to contemporary composers and

[5] Aaron S. Allen, "Ecomusicology: Ecocriticism and Musicology", *Jorunal of the American Musicological Society*, 64 (2), 2011, 392.

listeners a version of a piano that is oriented towards the innovative performance methods that were developed by various composers over the last few centuries, thus bringing the instrument closer to the musical thinking of our epoch.

Consequently, the main aims of piano modification were:

- To develop new means of sound production;
- To expand the range of piano timbre;
- To modify the tuning system of piano that is based on equal temperament in a free and more natural way;
- To create a more comfortable environment for the production of the piano sonorities of the 21st century, taking into consideration advanced piano performance techniques developed by composers in the last two centuries.

To achieve these aims, the following changes were made while modifying the instrument (Figure 1):

Figure 1: The ModEkAl

- A harp string has been attached to the instrument's body in front of the keyboard;
- The functions of the piano pedals have been modified;
- Various materials have been attached to the hammerheads;
- The strings of the instrument have been tuned according to the principles of microtonal music and the atomic-nuclear musical system;
- As a result of changing the tuning system, the keys were painted in different colours for orientation purposes;
- The instrument's body has also been changed for the convenience of playing in the strings – the wood-covered part of the modified piano body has been partly cut out and replaced with a polycarbonate sheet attached to the top board hinge. The sheet can be removed during playing.

Let's describe all those modifications in a more detailed way.

A harp string attached in front of the keyboard can be used for various ways of sound production. The pianist can play the string imitating any string player, sliding along the string with the left-hand fingers, determining the pitch, and playing it with a bow using the right hand. He can produce various effects on this string, such as pizzicato, overtones, glissando, sul ponticello, saltando, etc. The string can even be played simultaneously with the keyboard if the pianist uses the thumb of his left hand (that plays the keyboard) for moving along the string and employs his right hand to pluck the string or play with a bow. The string is connected to the resonator board to sound at the appropriate volume. They are connected with the 60 cm long wooden stick through the hole on the key-bed (Figure 2). One end of the stick touches the board and the other end is covered with metal that serves as a bridge for the string stretched between the side arms of the piano. The piano tuning-pin attached to the right side arm of the piano is used for tuning the string.

The pedal system (Figure 3) of the ModEkAl includes three pedals (initially the upright piano "Zarya" had two pedals); they have two different functions: the left pedal produces overtones, the middle and right pedals sustain the sound.

(1) *Sustain (damper) pedals*. The right damper pedal of the upright piano was transformed into two independent pedals. A new (middle) pedal was added with the function of partially opening the dampers (thereby, the instrument creators restored the idea of the John Broadwood and Sons' piano pedals dating back to the 18th and 19th

centuries); the middle pedal affects only the lower registers (up to the fourth octave), the right pedal – only the upper registers (starting from the fourth octave up to the seventh octave). The mechanism of the middle pedal works like a typical sustain pedal, but it affects only the dampers in the low register because the damper lift rod is shortened. The mechanism of the right pedal works differently: the pedal rail is located on the right side; it is connected with the pedal rod and when the pedal is activated it moves up and pushes at the same time another additional pedal rod that moves down and affects the damper lift rod, which opens the dampers of the strings in the high register. To open the dampers of the strings in all the registers, the pianist can depress the middle and right pedals with the right foot that adds the fourth function to the pedal system.

Figure 2: The wooden stick connecting the harp string to the resonator board

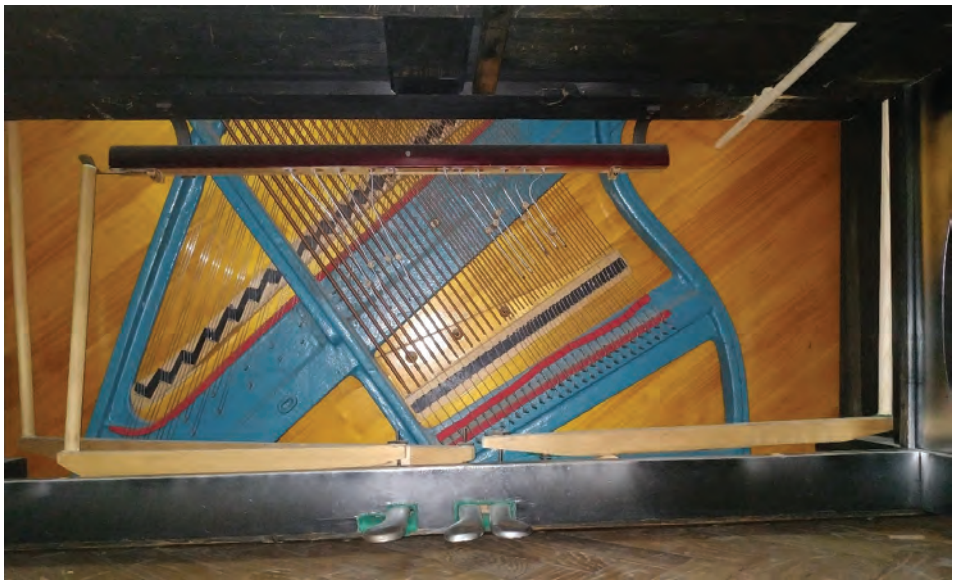


Figure 3: The pedal system of the ModEkAl

(2) *Overtone pedal*. The soft pedal of the "Zarya" piano has been converted into an overtone pedal. The left pedal can be fixed as a harp pedal. It has two functions: when not pressed down, it produces overtones, and when pressed down, it produces the regular pitches. The mechanism that produces overtones is attached to the key-bed. This is an additional rail (defined by us as an *overtone rail*), to which several wires of different lengths are attached. One damper drum is put on each wire and each wire serves one string. When the pedal is not pressed down, being in an open position, the damper drums softly touch the strings and produce overtones. It is possible to move the damper drums along the wires and change the overtones. However, this mechanism functions only in the case of ten white keys in the low register. In the case of the grand piano modification, it would be possible to produce overtones of all the white keys. The soft pedal rail of the "Zarya" has been left untouched and the pedal rod was shortened. When the left pedal is pressed down, the soft pedal rod pushes the half-blow arm connected with the new overtone rail with wires and damper drums, the rail moves up from the strings and the ModEkAl produces regular pitches.

The cover materials of the hammerheads have been replaced with various materials: 39 hammerheads were left untouched, covered with felt, the others were covered with wood (14), metal (12), rubber (9), leather (7), and cardboard (4). The materials of the hammerhead covers affect the timbre, dynamics, and weight of the keys. Hammers covered with rubber and metal are regulated through piano key leads so that the corresponding keys do not become too heavy.

The keyboard has been significantly influenced by changing the hammerheads' materials and the tuning system. The ModEkAl's coloured keyboard represents a combination of Acoustic Islands and Timbre Spaces, the concept of which is based on the tuning system of the ModEkAl.

- *Acoustic Islands* – red and white keys of the modified piano defined by us as musical Atoms. Hammers connected with the keys representing Acoustic Islands were left untouched – covered with felt;
- *Timbre Spaces* – keys of various colours between Atoms tuned in the ModEkAl's tuning system. Key colours indicate the materials used to cover hammerheads that determine the character of the timber: the yellow keys are associated with wooden hammerheads; blue – with metal; brown – with leather; black – with rubber, and beige – with cardboard.

The keys have been painted in different colours to help the pianist to orientate while playing.

2. Tuning System of the ModEkAl

2.1 Description of the ModEkAl's Tuning System

While modifying the instrument, we aimed at choosing the particular principle of the piano tuning system that would make the instrument a part of an ecosystem. Absolute symmetry does not exist in the universe and it is not typical for the ecosystem either.

The equal temperament tuning system of the piano was replaced by a new, ModEkAl tuning system that is based on the *atomic-nuclear musical system* invented by Eka Chabashvili. This new system includes harmonics of two different fundamental C-tones of the following frequencies: 16.384Hz and 131.072Hz. The ModEkAl has two layers of tuning that cross each other: the sequences of harmonics and randomly taken free frequencies which construct the so-called *Enriched Tones*.

The atomic-nuclear system aims to organize pitches in such a way that they associatively resemble the structure of an atom with electrons *moving*

through acoustic points in different trajectories around the nucleus. However, in the case of the piano, and not orchestra or ensemble, the sound remains rather constant and static. The distance between the extreme pitches of the Atom has to be no less than the interval of 333 cents. The fundament of this musical system is the Enriched Tone representing the central pitch (Nucleus) that is surrounded by several microtones (Electrons). The Enriched Tone contains one or more micro intervals of randomly chosen cents. The structure of the Enriched Tone is not strictly defined; the only rule is that the interval between the extreme tones of the Enriched Tone (Nucleus) has to be no more than 333 cents. The main principle for a model of the Enriched Tone is that it includes micro intervals within the range mentioned above. As for Electrons, they either move or are located around the Enriched Tones on the orbits with different distances from the Nucleus.

The musical Atoms of the modified piano are called Acoustic Islands and there are seven of them in various registers of the ModEkAl. On the keyboard, the centre of each Atom (Nucleus) is painted in red and the surrounding Electrons are painted in white. The coloured keys between the Atoms are Timbre Spaces. There are 10 Timbre Spaces on the keyboard.

On the ModEkAl, each key's corresponding pitch depends on the number and combination of the strings tuned separately to different frequencies. The pitches of the piano keys corresponding to the Nuclei (red keys) are presented with the Enriched Tones (except the Nucleus of the first Atom; this key has only one string). Also, many of the keys with 2 or 3 strings within the Timbre Spaces are tuned according to the Enriched Tone principle. Of course, the lowest 12 keys of the piano cannot produce the Enriched Tones as they have only one string.

The ModEkAl has seven octaves produced within the harmonics sequence of the C-note. Each of the seven octaves of the modified piano contains one Atom. Seven musical Atoms are associated by us with five Carbon and two Oxygen atoms. Carbon and Oxygen are the two main chemical elements that serve as the source for the creation of living organisms. According to Mendeleev's Periodic Table, the Carbon atoms consist of four outer electrons and Oxygen atoms – of six outer electrons arranged around the nucleus. Consequently, each musical Atom associated with Carbon atoms contains five keys (four Electrons plus one Nucleus), and each Atom associated with Oxidant atoms, respectively, has seven keys (six Electrons plus one Nucleus)[6].

[6] Here we see how natural science serves as a source of inspiration for Chabashvili's artistic idea that is implemented within the artistic research project.

2.2 The Tuning Table and Explanations

Table 1 presents the Tuning Table that covers both – equal-tempered tuning and its modification.

Table 1. ModEkAl Tuning Table

Piano keys	Tempered tuning frequencies (Hz)	New tuning frequencies for each string (Hz)		Material for hammers	Other
Sub-contra octave					
A_0 (1 string)	27.50	28.00		Wood	
$A^{\#}_0/B^{b}_0$	29.14	**23.70**		Metal	Bell
B_0	30.87	31.15		Wood	
Contra-octave					
C_1	32.70	33.73			Overtone
$C^{\#}_1/D^{b}_1$	34.65	**32.768**			Overtone
D_1	36.71	Same			
$D^{\#}_1/E^{b}_1$	38.89	37.76			Overtone
E_1	41.20	39.88			Overtone
F_1	43.65	45.66		Wood	
$F^{\#}_1/G^{b}_1$	46.25	47		Wood	
G_1	49.00	49.152		Wood	
$G^{\#}_1/A^{b}_1$	51.91	51.19		Wood	
A_1 (2 strings)	55.00	52.7	53.5	Rubber	
$A^{\#}_1/B^{b}_1$	58.27	55	57	Rubber	
B_1	61.74	58.7	61	Rubber	
Great octave					
C_2	65.41	**65.536**		Rubber	
$C^{\#}_2/D^{b}_2$	69.30	68	70.30	Rubber	
D_2	73.42	81.92			Overtone
$D^{\#}_2/E^{b}_2$	77.78	75.00			Overtone
E_2	82.41	73.42			Overtone
F_2	87.31	85	Same		

$F^{\#}_2/G^{b}_2$	92.50	90.80			Overtone
G_2	98.00	98.304			Overtone
$G^{\#}_2/A^{b}_2$	103.83	100.59			Overtone
A_2	110.00	105	Same	Cardboard	
$A^{\#}_2/B^{b}_2$	116.54	114.688		Cardboard	
B_2	123.47	125.59	122.00	Cardboard	
Small octave					
C_3	130.81	131.072		Cardboard	
$C^{\#}_3/D^{b}_3$ (3 strings)	138.59	135	138	142	Wood	
D_3	146.83	147.456		Wood	
$D^{\#}_3/E^{b}_3$	155.56	153	158	160	Wood	
E_3	164.81	163.84		Wood	
F_3	174.61	192			
$F^{\#}_3/G^{b}_3$	185.00	186			
G_3	196.00	180.224			
$G^{\#}_3/A^{b}_3$	207.65	196.608	Same	210		
A_3	220.00	212.992			
$A^{\#}_3/B^{b}_3$	233.08	229.376			
B_3	246.94	245.76			
I octave					
C_4	261.63	262.144		Leather	
$C^{\#}_4/D^{b}_4$	277.18	274	278.528	280	Leather	
D_4	293.66	283	294.912	300	Leather	
$D^{\#}_4/E^{b}_4$	311.13	305	311.296	315	Leather	
E_4	329.63	323	327.68	337	Leather	
F_4	349.23	340	344.064	355	Leather	
$F^{\#}_4/G^{b}_4$	369.99	376.832	360.448	409.6	Leather	
G_4	392.00	415			

$G^{\#}_4/A^{b}_4$	415.30		393.216			
A_4	440.00	425.984	Same	442.368		
$A^{\#}_4/B^{b}_4$	466.16		458.752			
B_4	493.88		491.52			
II octave						
C_5	523.25		**524.288**		Metal	
$C^{\#}_5/D^{b}_5$	554.37	475.136	507.904	540.672	Metal	
D_5	587.33	557.056	573.44	589.824	Metal	
$D^{\#}_5/E^{b}_5$	622.25	606.208	622.592	638.976	Metal	
E_5	659.25	660	655.36	679	Metal	
F_5	698.46		740			
$F^{\#}_5/G^{b}_5$	739.99		701			
G_{5s}	783.99	786.432	Same	805		
$G^{\#}_5/A^{b}_5$	830.61		829			
A_5	880.00		850.47			
$A^{\#}_5/B^{b}_5$	932.33	Same	917.504	Same	Wood	
B_5	987.77	Same	950.4	Same	Wood	
III octave						
C_6	1046.50		**1048.576**		Wood	
$C^{\#}_6/D^{b}_6$	1108.73	Same	1080	Same	Wood	
D_6	1174.66		1254			
$D^{\#}_6/E^{b}_6$ (without dampers)	1244.51		1179.648			
E_6	1318.51	1310.72	Same	1365		
F_6	1396.91		1400			
$F^{\#}_6/G^{b}_6$	1479.98		1441.792			
G_6	1567.98	1480	1500	1572.864	Rubber	
$G^{\#}_6/A^{b}_6$	1661.22	1470	1640	1765	Rubber	

A_6	1760.00	1703.936	Same	1800	Rubber	
$A^{\#}_6/B^{b}_6$	1864.66	1835.008	1900	1966.08	Rubber	
B_6	1975.53		2097.152			
IV octave						
C_7	2093.00		1983			
$C^{\#}_7/D^{b}_7$	2217.46	2157	Same	2228.224		
D_7	2349.32		2359.296			
$D^{\#}_7/E^{b}_7$	2489.02		2490.368			
E_7	2637.02	2600	2621.44	2660	Metal	
F_7	2793.83	2700	2752.512	2883.584	Metal	
$F^{\#}_7/G^{b}_7$	2959.96	2900	Same	3014.656	Metal	
G_7	3135.96	3050	3145.728	3200	Metal	
$G^{\#}_7/A^{b}_7$	3322.44	3276.8	3370	3400	Metal	
A_7	3520.00	5407.872	3538.944	3620	Metal	

As one can see, the Atoms don't follow the principle of the horizontal ascending-descending linear arrangement of the pitch order – Electrons surround the Nuclei spatially, on a circular basis. 17 frequencies break the horizontal ascending-descending linear sequence. In the Tuning Table, 10 of them are marked in green, 6 – with various shades of blue (as harmonics are marked with blue and 6 frequencies mentioned above are included in the sequence of harmonics), and 1, the lowest pitch corresponding to the key $A^{\#}_0/B^{b}_0$ is defined as a *Bell*. The pitches of the Electrons don't make the Enriched Tone, even in the section of keys with three strings. The pitches of the Electrons in two lower register Atoms can be replaced with the overtones produced with pedals.

Here is the list of musical Atoms that contain the central Enriched Tones surrounded by the Electrons (in the Tuning Table the Nuclei are marked in

red and the Electrons – in white). The note names correspond to the traditional piano key layout:

- Atom I-Centre D [C_1-E_1; Island's area=340.05cents] +4 electrons (transforming into overtones);
- Atom II-Centre F [D_2 – $G^{\#}{}_2/A^{b}{}_2$; Island's area=545.09cents] the Enriched Tone with one micro interval [46.42cents] +6 electrons (transforming into overtones);
- Atom III-Centre As [F_3 – B_3; Island's area=536.950cents] the Enriched Tone with three micro intervals [114.08cents] +6 electrons;
- Atom IV-Centre A [F_5 – A_5; Island's area=386.313cents] the Enriched Tone with three micro intervals [65.337cents] +4 electrons;
- Atom V-Centre G [D_6 – $F^{\#}{}_6/G^{b}{}_6$; Island's area=334.615cents] the Enriched Tone with three micro intervals [40.4cents] +4 electrons;
- Atom VI-Centre E [G_4 – B_4; Island's area=347.407cents] the Enriched Tone with three micro intervals [70.249cents] +4 electrons;
- Atom VII-Centre Cis [B_6 – $D^{\#}{}_7/E^{b}{}_7$; Island's area=394.409cents] the Enriched Tone with three micro intervals [56.241cents] +4 electrons.

While retuning the piano, we retained the frequencies of several strings, especially of those included in Atoms' Nuclei (in the Tuning Table, 7 retained frequencies are marked in red and indicated by the word *same*). In the sector consisting of three-string notes, the middle strings are tuned based on the equal temperament tuning system, as a central pitch of the Enriched Tone, the other two strings are tuned higher and lower to various frequencies. The nine strings of the Timbre Spaces also retain their original frequency (the colours which indicate the keys of the Timbre Spaces in the Tuning Table are the same as on the keyboard).

The tuning of 63 strings out of 215 is based on the 39 harmonics of the fundamental C-tone of 16.384Hz and 27 harmonics of the fundamental C-tone of 131.072Hz; they share three harmonics (in the Tuning Table, 39 harmonics are marked in blue, 27 harmonics – in green-blue; three common harmonics are also marked in green-blue, and the harmonics producing C pitches in different registers are given in dark blue).

The ModEkAl has seven perfect octaves given between the C pitches (in the Tuning Table the C pitches are marked in dark blue):

I – 32.768Hz – $C^{\#}_1/D^{b}_1$ Key (I Atom)
II – 65.536Hz – C_2 Key (Timbre Space of rubber hammerheads)
III – 131.072Hz – C_3Key (Timbre Space of cardboard hammerheads)
IV – 262.144Hz – C_4Key (Timbre Space of leather hammerheads)
V – 524.288Hz – C_5Key (Timbre Space of metal hammerheads)
VI – 1048.576Hz – C_6Key (Timbre Space of wooden hammerheads)
VII – 2097.152Hz – C_7Key (VII Atom)

One hundred strings out of 215 belong to the Acoustic Islands, where 21 strings of Atoms are tuned within harmonics sequences. 115 strings belong to the Timbre Spaces, 42 strings of them are tuned within the harmonics sequences. One hundred and fifty-two strings are freely tuned based on the principle of the relationship between the frequencies based on the atomic-nuclear music system. One hundred and four strings produce Enriched Tones, 17 of them belong to the keys of Nuclei, 87 strings of 104 belong to the keys of the Timbre Spaces.

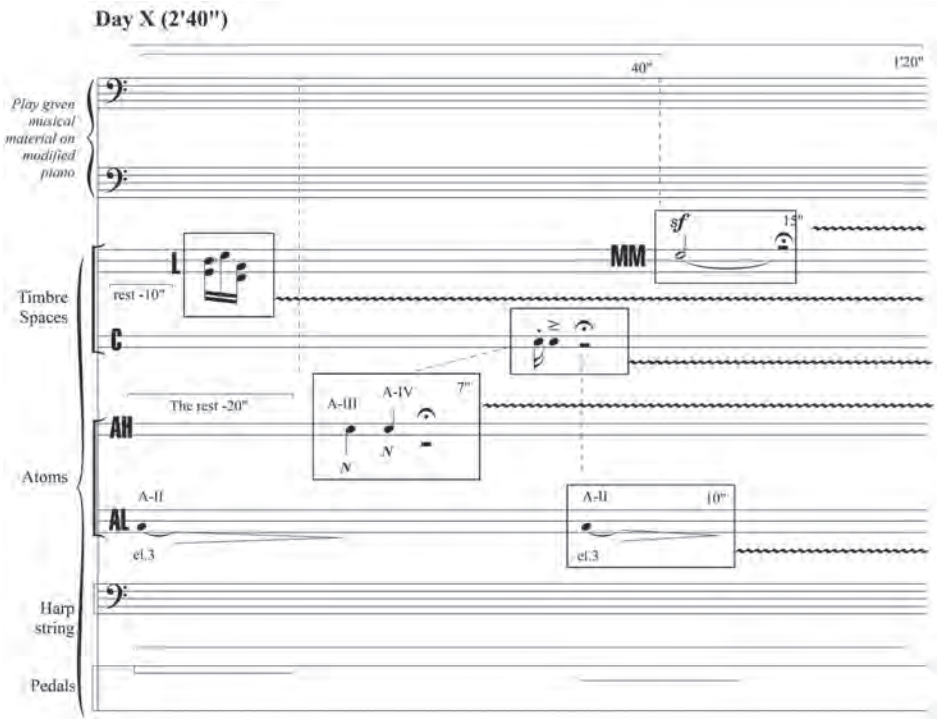
The ModEkAl contains 37 Enriched Tones; six of them are Nuclei within Acoustical Islands (six Atoms), and 31 Enriched Tones are distributed within the Timbre Spaces of various registers:

- The Timbre Space of the metal hammerheads contains 10 Enriched Tones;
- The Timbre Space of the rubber hammerheads contains 8 Enriched Tones;
- The Timbre Space of the leather hammerheads contains 6 Enriched Tones;
- The Timbre Space of the wooden hammerheads contains 5 Enriched Tones;
- The Timbre Space of the cardboard hammerheads contains 2 Enriched Tones.

3. The ModEkAl and Notation

Modifying the instrument has led to the creation of corresponding notation. Figure 4 presents the ModEkAl part from the score of the piece *Anamnesis of Covid-19* (Figure 4).

Figure 4: *Anamnesis of Covid-19*, score



There are 7 staves used for the distribution of the musical material played on the ModEkAl. The upper 2 staves are intended for the Timbre Spaces to be played with both hands. The Timbre Spaces are designated by the abbreviations where the first letter indicates hammerhead material: W-wooden (yellow keys), M-metal (blue), L-leather (brown), R-rubber (black), and C-Cardboard (beige). Particular materials are used to cover the hammerheads in different registers. To define the registers, the composer uses the second letter of the abbreviations indicating the location of the keys in either the High, Middle, or Low registers (for instance, WH means the Wooden hammerhead in the High register). The abbreviation corresponding to the lowest three keys is WMW (Wooden-Metal-Wooden).

The next 2 staves are intended for Acoustic Islands (Atoms). Instead of clefs, for the high and low register Atoms are used with the abbreviations AH and AL. On the staves presented by two or three lines, written notes indicate key locations within particular Timbre Spaces or Acoustic Islands.

The ordinary five-line staff belongs to the harp string – open string E.

The lowest 2 lines are given for pedals: the upper line – for the middle and right pedals used for the High and Low registers and the other line – for the left overtone pedal with two positions indicated either by F (flageolet) or Ord. (ordinary – the pedal is pressed down).

Seven Atoms are numbered starting from the lowest AL(ow) – I, II, III (keys Nos. 1–39) to the high register – IV, V, VI, VII (keys Nos. 40–85). The number of the Atom is notated above the staff: for example, A-I, A-II, etc.

Notation of Atoms. The pitches constituting Atoms are written on a two or three-line staff system. Nuclei are written in the middle of the staff lines. They are denoted by the Latin Letter *N*. Around the Nucleus the Electrons are located, which are indicated by the Latin letters *el.1, el.2,* etc. The Electrons are marked according to their left-to-right position on the keyboard.

Seven Atoms are presented on the keyboard. As mentioned above, 5 of them are associated with Carbon atoms, thus consisting of a Nucleus and four Electrons (in total 5 musical notes), and 2 – with Oxygen atoms consisting of a Nucleus and six Electrons (in total 7 musical notes). Therefore, on the two-line staff system five-note Atoms are notated, and on the three-line system – seven-note Atoms.

Notation of Timbre Spaces. The registers on the keyboard are divided into three parts: High (keys Nos. 57–85), Middle (keys Nos. 29–56), and Low (keys Nos. 1–28). Timbre Spaces located between Atoms are indicated with the Latin letters corresponding to the material of the hammerheads and their location within the particular registers of the ModEkAl. For example, if the hammerhead covering material is Wood, we take the first letter of the word – W and attach it to the first letter of the word in which register this Timbre Space is located: in the upper – H, in the middle – M, in the lower – L.

The symbol of the high register keys with a wooden hammerhead is WH and it has to be written in front of the note on a two or three-line staff system instead of a clef. The notes arranged on the lines correspond to the keys from left to right (the first note is written under the first line of the staff). As these colours are used as a guide when playing on a coloured keyboard, the performer needs to know which colour is associated with which hammer:

M (*Metal*) *blue keys*: MH sounds are located in the Timbre Space of VII Atom; MM sounds – between IV and V Atoms;
W (*Wooden*) *yellow keys*: WH sounds are located between V and VI Atoms; WM – between II and III Atoms; WL – between I and II Atoms;
L (*Leather*) *brown keys*: L sounds are located between III and IV Atoms;
R (*Rubber*) *black keys*: RH sounds are located between VI and VII Atoms; RL – between I and II Atoms;
C (*Cardboard*) *beige keys*: C sounds are located between II and III Atoms.
The lowest 3 keys – *yellow/blue/yellow* – are indicated by WMW (wooden/metal/wooden hammerheads).

Thus, the Timbre Space sounds are notated on the staff lines in a sequence from the bottom to the top; it must be noted that the lowest tone is always written under the first line of the staff and for upper tones additional lines may be required. For example, if brown keys' sounds are placed on a two-line staff, we will need upper additional lines. It is possible to place notes of two or more Timbre Spaces on the same staff (but not over each other). In this case, abbreviators of particular Timbre Spaces have to be written before these notes.

In the score, some excerpts of the piece sometimes are notated on five-line staves with traditional musical symbols. It is much easier for performers to perceive complicated textures imitating the piano repertoire (in our particular case – quotations from various works of previous centuries) denoted by conventional symbols. Thus, music composed for the ModEkAl can be notated traditionally, though notated pitches will sound differently.

4. Conclusion: The Future of the ModEkAl and Piano Music

The main challenge for our research remains the future of the instrument. The question is whether the ModEkAl will be able to go beyond the boundaries of one-time experiments conducted within the research and to establish itself as an instrument that will inspire composers to create new works and encourage pianists to perform them.

We have introduced ModEkAl at various international conferences and forums, as well as festivals (Delft Chamber Music Festival 2021). Several composers have already expressed their interest and wish to compose for the modified piano. That's why we hope we gave our answer to the question reflected in the title of our artistic research.

You can listen to the ModEkAl, as well as the piano piece *Anamnesis of Covid-19* which is part of a large multimedia piano performance "Has Piano Music Come to an End?" at the following link: https://www.youtube.com/watch?v=cDHdQ8uVQvo&t=3686s (the ModEkAl piece starts at 50:17).

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Summary

For the majority of contemporary composers, the field of interest is electroacoustic music. On the one hand, the capabilities of classical instruments often no longer satisfy composers – they see more creative potential in music programming. On the other hand, this interest is driven by the composers' desire to have their works performed, the realization of which is much easier at the expense of technologies. These

trends have created a shortage of new sounds in instrumental music. It is important to maintain instrumental music and to make its existence suitable for the modern environment.

To solve this problem, an upright piano, "Zarya", which was manufactured in the Soviet Union in the 70s of the previous century, was modified according to the principles of modern musical thinking and ecomusicology that is very topical nowadays into the Eco-Piano ModEkAl. The modified piano is a new type of piano constructed for the artistic research entitled *Has Piano Music Come to an End?* conducted by composer Eka Chabashvili and pianists Nino Jvania and Tamar Zhvania. The piano was modified according to Eka Chabashvili's scheme, which was enriched with the ideas of piano master Alexander Zirakashvili. The name of the instrument derives from a combination of the names of its creators – Piano Modified by Eka and Alexander.

A musical instrument always echoes the epoch it was created in. With its structure, tuning system, and performance techniques, it could be considered a musical chronicler that tells a lot about the musical aesthetics of the age it belongs to. The principles of musical thinking characteristic of any new epoch lead to the transformation of the instrument, its renewal, refinement, or the enrichment of its performance techniques. Each era adapts the instrument to the principles of the corresponding musical thinking so that instrument's sound has a truly contemporary essence. When modifying any instrument, it is necessary to take into consideration the cultural memory stored in it. We have numerous vivid examples of instrument modifications (ancient flute, antique hydraulic and contemporary electronic organs). In all cases, the instruments retain their essence.

The purpose of the article is to present the Eco-Piano ModEkAl and to describe the principle and process of modification, as well as to introduce a new notation system designed exclusively for the ModEkAl.

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